A pplied
N atural
S ciences

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January 22, 2001

Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

Attn: James Wozniak

Re: 2000 Site Activity Report

Dear Jim,

This letter is being provided to document Applied Natural Sciences, Inc. (ANS) results and recommendations from the Summer and Fall 2000 site visits for the 317/319 Phytoremediation Project. The Summer site visit was conducted August 9-11, 2000 and involved primarily clearing and mowing activities. The Fall visit was conducted September 27-29, 2000 and involved the evaluation of tree height and growth conditions.

SUMMARY

The attached site map provides data on tree height and vigor (see rating system described below) for each tree within the distinct areas of the site. Averages for each delineated area and each row within that area suggest that for the most part, tree vigor was Good and tree height averaged between 6 and 7 feet. A notable exception in average tree vigor was found for the shallow-rooted trees in the 317 South Area. These trees rated Fair in vigor and may reflect the condition where many of these trees required replanting during the Spring, 2000. The Waste Trench Area, also shallow planted, averaged only Fair in vigor and many of these trees also required replanting during the Spring, 2000.

In general, the growth and vigor of the trees are about as good as could be expected considering the late 1999 planting and the cooler than normal growing conditions realized in 2000 (see Growing Degree Day data below). To help qualify the effect of the cooler growing conditions, Argonne growth and vigor data were compared data derived from another ANS *TreeWell™* site. At the *TreeWell* site in Staten Island, New York, tree vigor was generally Very Good and tree height averaged between 9 and 10 feet at the same stage of development (see Attachments - Pictures 1 and 2). Based on this comparison and years of observation of similar phytoremediation systems, it is almost certain that the growth limiting conditions at Argonne, described below, adversely affected the height and vigor of these trees for the 2000 growing season.

BACKGROUND

The 317/319 Phytoremediation Project was planted late in the spring and early summer of 1999. Hybrid poplar trees were planted to hydraulically mitigate groundwater flow and remove a number of volatile organic compounds, including trichloroethylene, 1,1,1-trichloroethane, and 1,1-dichloroethane, and tritium in the groundwater of the deeper aquifer located 25 - 30 feet below ground surface. ANS employed its patented *TreeWell™* system to overcome the problem that a shallower uncontaminated perched aquifer (located 10-12 feet below ground surface) presented. With the *TreeWell™* system, rainwater and the shallow aquifer are sealed off from poplar tree's root

system (see Attachments - Figure 1). Ultimately, the trees are able to use only the deep groundwater and thus effect the contaminant removal and hydraulic mitigation required.

RESULTS

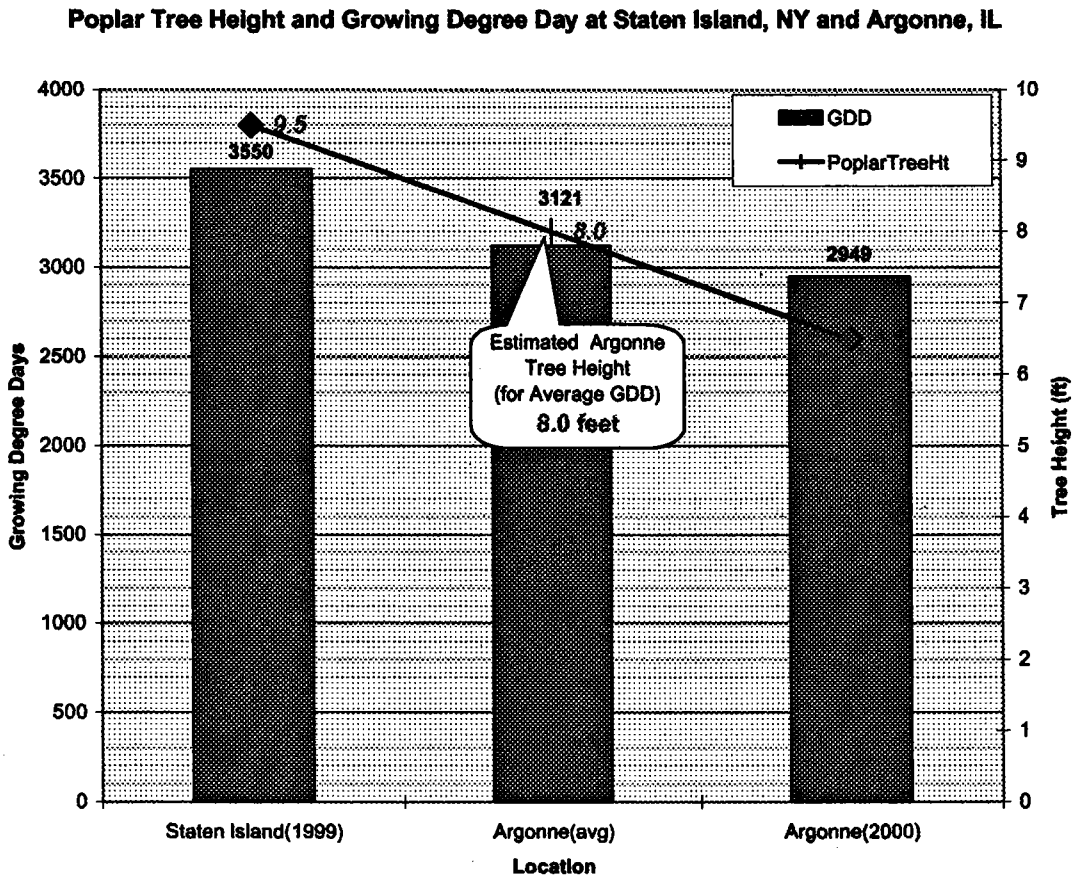
2000 Growing Conditions

At an ANS site in Staten Island, NY a comparable *TreeWell* system was established in 1998. In addition to the planting method and hybrid poplars used, the temporal setting for the planting on Staten Island was virtually identical to the late planting at Argonne. While the site is located in a climatically warmer area, it was observed that, like Argonne, the late- planted trees showed very little growth the year of planting. However, tree height at the end of the second growing season averaged between 9 and 10 feet at Staten Island while tree height at the end of the second growing season at Argonne averaged 6 to 7 feet (see below and Attachments – Pictures 1 and 2, 317/319/French Drain Site Maps). While some growth advantage could be expected for Staten Island due to its warmer climate as reflected in its higher growing degree day (GDD) value of about 3550 compared to Argonne's 3 year average of about 3121, Argonne was further disadvantaged in 2000 by cooler than average conditions resulting in a year with 5.5% fewer GDDs (see Table and Chart below). In short, these data indicate that because Argonne, 2000 GDDs were lower than normal, tree growth was less than expected. The cooler conditions would also reduce tree vigor ratings.

Growing Degree Day* Period	1998 GDD	1999 GDD	2000 GDD	Three Year Average GDD (1998-2000)
May 1 - July 31	1918	1968	1643 (–11%)	1843
August 1 – October 31	1368	1158	1306 (+2%)	1278
Growing Season	3286	3126	2949 (-5.5%)	3121

- - Growing Degree Days are calculated by cumulatively adding the value of the average daily temperature (ADT) that is greater than 50F (i.e. if ADT>50 then ADT-50 for a given day is cumulatively added to a running total for the growing season). GDD is used as an indicator parameter for vegetative growth potential in a climatic zone.

The chart below provides an estimate of the height that the trees at Argonne could have achieved if growing degree days had been more typical by accounting for annual growing degree days. This estimate also assumes that the Argonne 2000 tree height is properly reflected by the annual GDD value. It is arguable that even this annual disparity of GDD doesn't completely reflect the cooler than average condition realized during the 2000 growing season at Argonne. For a plant to realize its full growth potential for the year, there must be a significant amount of growth occurring in the first half of the growing season. However, during the first half of the 2000 growing season, GDDs were 11% below the 3 year average levels while the second half of the growing season, GDD levels for 2000 tallied nearly 2% more than the 3 year average (see Table above). In other words, the disparity during the important early growing season was much worse than the full season disparity and consequently, the 2000 tree height might be worse than would have been expected and, correspondingly, the tree height for average conditions might also be under estimated.



Summer Visit

During the Summer visit, planted grasses and volunteer weeds were found to have overgrown many areas of the site to the point that smaller trees were being shaded and generally inundated by the non-tree vegetation. It was also evident that large rocks and small boulders that were deposited on the surface during the *TreeWell*™ installation process would have to be cleared to permit any type of mowing activity. To deal with these problems and insure that weed-obscured trees weren't mowed or otherwise damaged, ANS performed the clearing and mowing activities.

Exposed rocks that were determined to be impediments to mowing were collected in a front-end loader and added to the rock barrier of the 319 drainage way. Approximately, 10 yards of rock were collected and removed from the 319/317 areas outside of the French Drain Area. Once the rocks were removed, a tractor mounted 5-foot Bush Hog mower was used to mow the weeds. Care was taken to avoid damage to the trees and thus preserve the integrity of the project.

Fall Visit

During the Fall visit, trees were evaluated to develop a baseline of tree growth and vitality. Tree height was measured and a ranking system was used to describe the overall growth and vigor of each tree. This ranking system employs a subjective zero to five scale that is qualified as follows:

0 = dead 1=poor, 2=fair 3=good 4=very good 5=excellent

From this scale, a tree that ranked below 2 may be a candidate for future replacement while a ranking of 4 or above suggested that the tree was growing vigorously and in a manner expected during optimum conditions.

French Drain Area

The willows in the French Drain Area were generally growing very well. Unlike poplars that tend to display more of their growth vertically, willows such as those in the French Drain tend to grow in diameter both in trunk girth and canopy and that is what is reflected here. Generally the willow trees in this area averaged 7.4 feet in height and reflected an average vigor of 2.8 or "Good" based on the scale provided above. Based on the GDD analysis, we would expect that under normal conditions, tree height and vigor would improve at least 10% over these values giving an average tree height of 8.1 feet and vigor would be expected to improve at least 1 unit to 3.8 or the "very good" range.

317/319 Areas

The poplar trees in the 317/319 area are divided into two groups; shallow-rooted and deep rooted. The shallow-rooted were planted like normal landscape trees where the roots are permitted to develop in the vadose zone of the upper horizons of soil. The deep-rooted trees were planted in the TreeWell holes to direct roots downward to intercept the deep groundwater.

The shallow-rooted poplars were generally taller than deep-rooted trees since they were planted with the root crown near ground surface versus several feet below ground surface for the deep-rooted trees and were predominantly HP510 hybrids. Correspondingly the deep-planted deep-rooted trees were predominantly HP308 hybrids. The shallow-rooted trees averaged 7.0 feet tall while the deep-rooted trees averaged about 6.4 feet tall with the notable exception of the 319-East area where the average height was 7.3 feet (these trees were planted slightly shallower).

Vigor on the other hand was better for the deep-rooted trees where the average was about 2.9 (Good) compared to the average 2.3 (Fair) for the shallow-rooted trees. This distinction can be accounted for by the late planting (August, 1999) of most of the shallow-rooted trees which substantially shortened the establishment period of the first year.

Based on the GDD analysis, we would expect that under normal conditions, tree height and vigor would improve at least 10% over these values giving an average tree height of 7.7 feet for the shallow-rooted trees and about 7 feet for most of the deep-rooted trees (319 East trees would be about 8 feet in height). Correspondingly, deep-rooted tree vigor would be expected to rise to at least 1 unit to 3.9 to "very good" range and shallow-rooted vigor would be expected to improve at least 1 unit to 3.3 or the "good" range or better.

Waste Trench

Willow trees in the waste trench suffered significant mortality and damage which was ironically attributable to the first year vigor of this group of early planted trees. Their noticable Fall, 1999 vigor seemingly delayed dormancy during the early part of the winter which was warmer than normal. When colder temperatures did take hold, significant freeze damage to the still-green base of these trees was witnessed. After more than 25% of the trees were replaced the average tree height for this area was 8.8 feet but due to the freeze damage, the overall vigor for this area was 2.0 (Fair). Based on the GDD analysis, we would expect that under normal conditions, tree height and vigor would improve at least 10% over these values giving an average tree height of 9.7 feet and vigor would be expected to improve 1 unit to at least 3.0 or "good".

CONCLUSIONS

Tree Height and Vigor

The 2000 GDD values correlate closely with what was observed in the field. That is, vegetative growth through July, 2000 was observably limited while growth from August through October was markedly positive. In fact, most of the visual growth that occurred during the 2000 growing season took place after July 31st. Accordingly, based on these observations and experience at other sites, we can conclude with some certainty that under more normal growing conditions we would expect better growth and vigor from the trees than were realized in 2000.

Cool Growing Season Effects – Nutrient Status

One additional perspective worth mentioning is the effect that cooler growing conditions had on tree appearance during the 2000 growing season. The primary effect of the cooler growing season relates to overall appearance of the plant. It is also common for plants growing in cooler than normal conditions to reflect nutrient deficiencies. These are not actual deficiencies that result from low soil nutrient status (as soil nutrient status was addressed at planting time and is quite adequate) but merely a reflection of the plant's metabolic imbalances. Apparent nutrient deficiencies, that aren't reflecting soil nutrient status, may be caused by:

1) temperature limited respiration,
2) temperature limited photosynthesis,
3) temperature limited root development,
4) temperature limited nutrient translocation from the root to the shoot,
5) temperature limited translocation of nutrition to the roots,
6) other related conditions, or
7) a combination of one or more of these items.

Cool Growing Season Effects –Pathogen Status

The second effect of this cooler growing season was the regional impact that the pathogen, fungal rust, had on poplar trees throughout the midwest. The rust was characterized by pin-head sized orange red bumps uniformly dispersed on the tops of the leaves. The damage to the plant is limited to the early loss of leaves and does not automatically carry over to the next growing season. Long before the rust spores appear on the leaves, some leaves turn yellow and fall from the tree giving the overall appearance of a poplar tree either undergoing drought conditions or having a nutrient deficiency (see Attachments – Pictures 1,3 and 4). These conditions were observed from eastern and southern Ohio to northern Illinois and southern Michigan in 2000.

Rooting Depth

TreeWell or deep-rooted trees will be expected to root to a depth of 20 or more feet to encounter the capillary fringe of the deep aquifer. Based on average root growth rates observed in root activity studies and root development empirically observed at other *TreeWell* sites, root development for the deep-rooted trees should generally 15 feet below ground surface. When the roots do reach the capillary fringe of the groundwater, it is typically evidenced by the changes in the morphology of the

apical leaves. They become significantly larger than the other leaves on the trees (2-4 times as large) which apparently reflects the luxury comsumption of water by the trees.

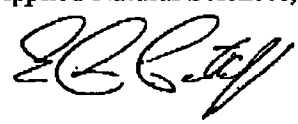
Intended rooting depth of the Waste Trench willow trees and the shallow-rooted poplars is 0 to 5 feet below ground surface. French Drain willows will be expect to achieve rooting activity to approximately 20 feet below ground surface (or the extent of the soil mixing depth). Deeper rooting by the French Drain willows should occur over a much longer time period due to the dewatering required of the mixed soil.

RECOMMENDATIONS

Expectations for growth and development of the trees in 2001 are generally very good provided more typical climatic parameters are realized. Some tree replacement will be necessary. Mowing and other weed control measures should be performed. Tissue sampling, root development and growth measurements should be accomplished towards the end of the 2001 growing season. Rooting depth evaluations should be accomplished in the spring and fall to determine root development rates.

Should you have any other questions regarding this submittal, please do not hesitate to contact me.

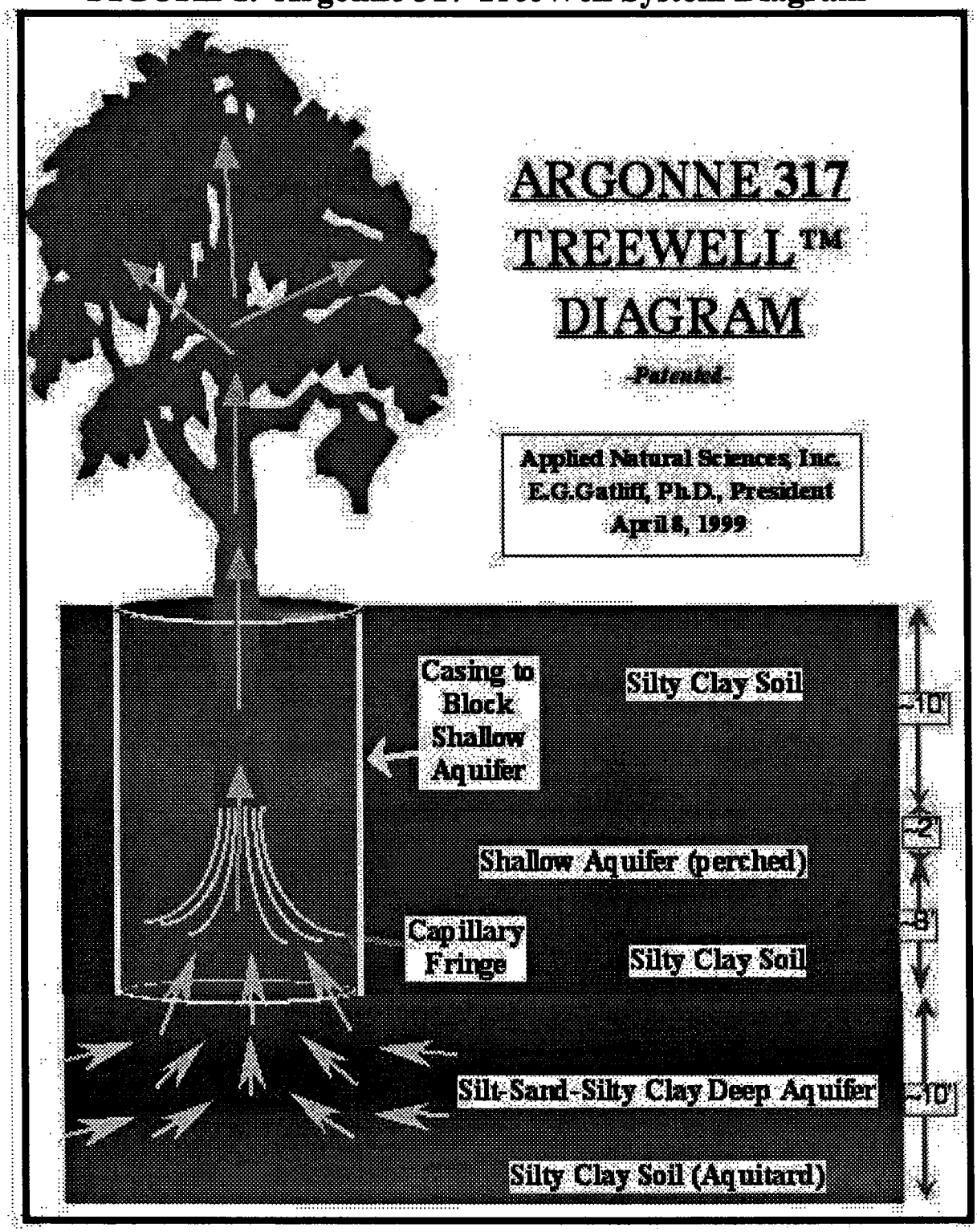
Sincerely,
Applied Natural Sciences, Inc.



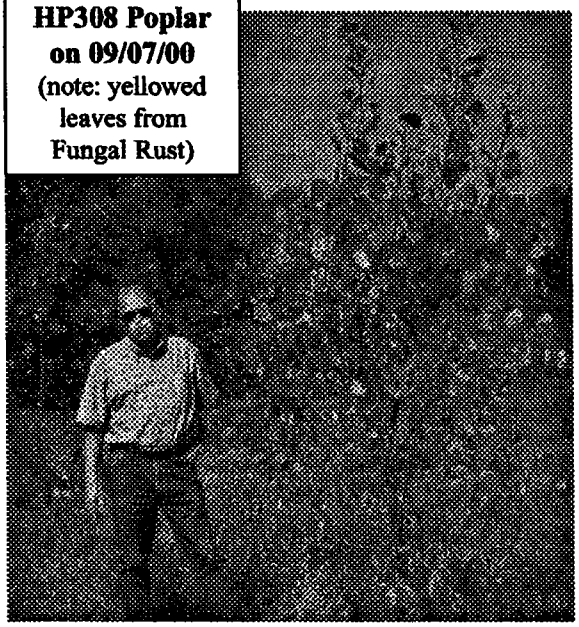
Edward G. Gatliff, Ph.D.
President

Attachments:

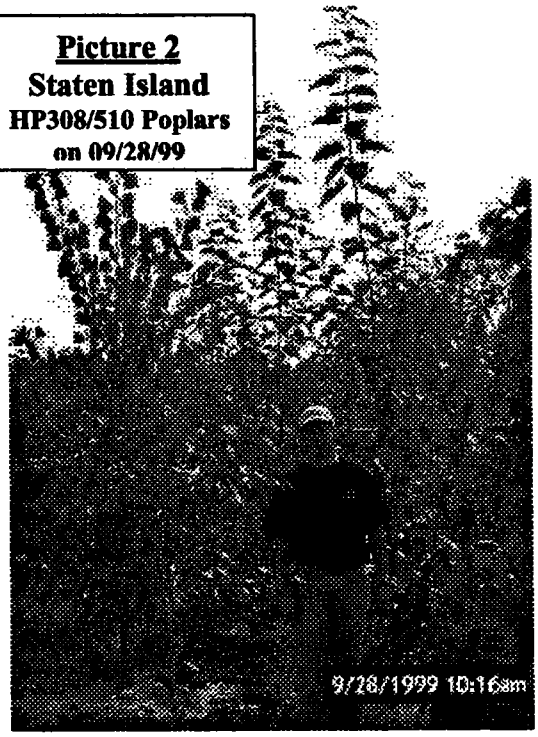
FIGURE 1. Argonne 317 TreeWell System Diagram



Picture 1
317 Area
HP308 Poplar
on 09/07/00
(note: yellowed leaves from Fungal Rust)



Picture 2
Staten Island
HP308/510 Poplars
on 09/28/99

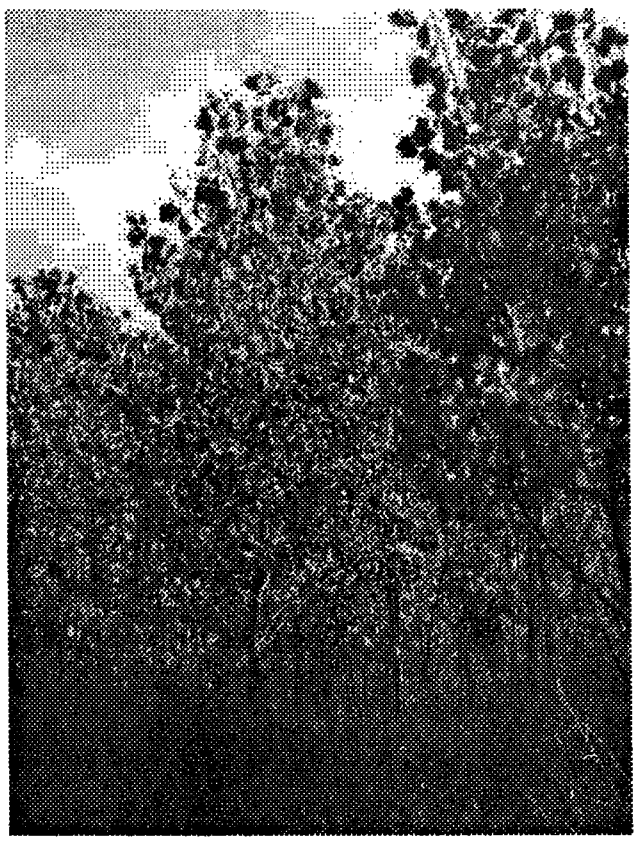


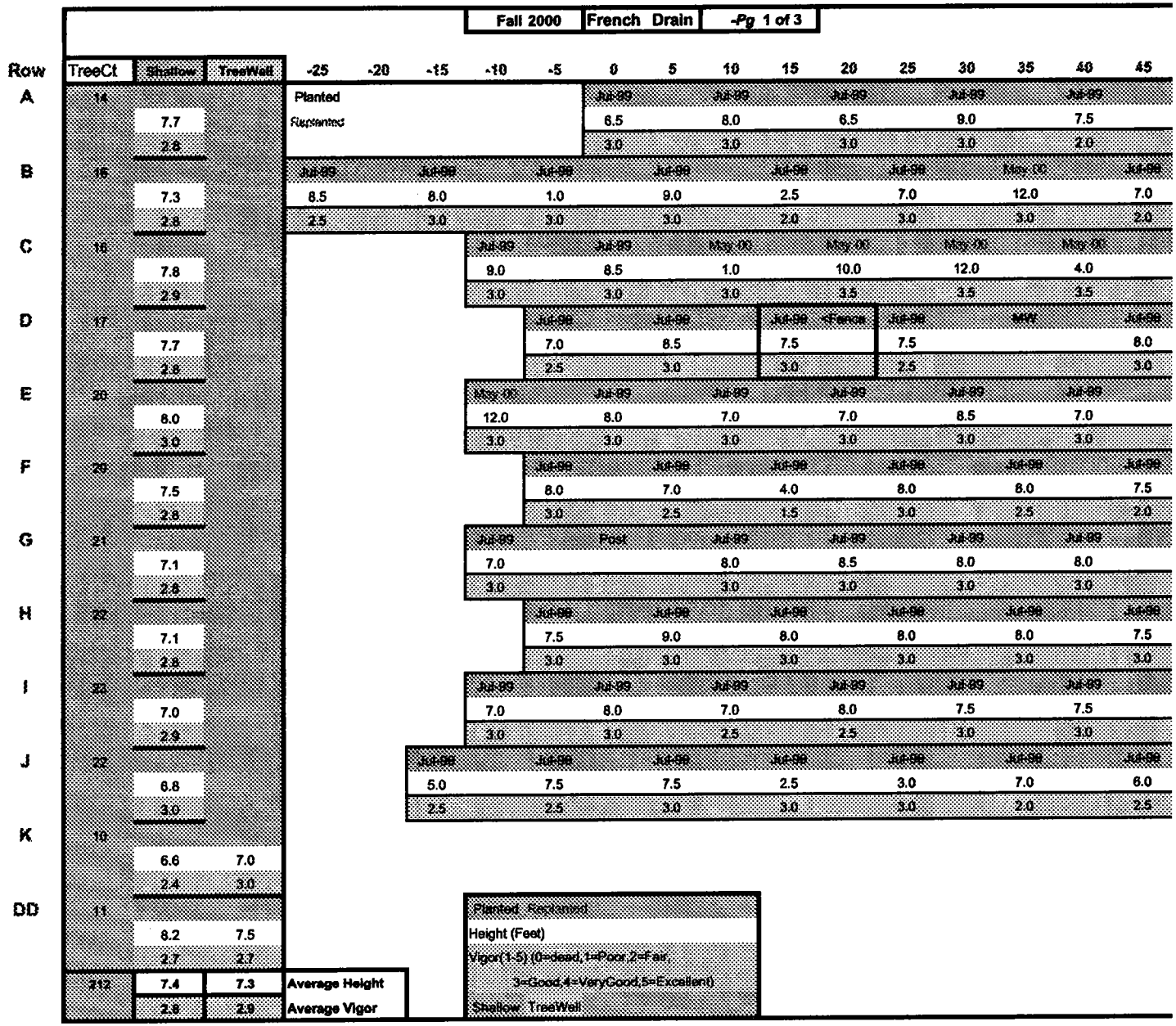
Picture 3 – **Fungal Rust damaged poplar tree leaves in Northeastern Ohio**

Picture 4

Fungal Rust damaged poplar trees in Northeastern Ohio

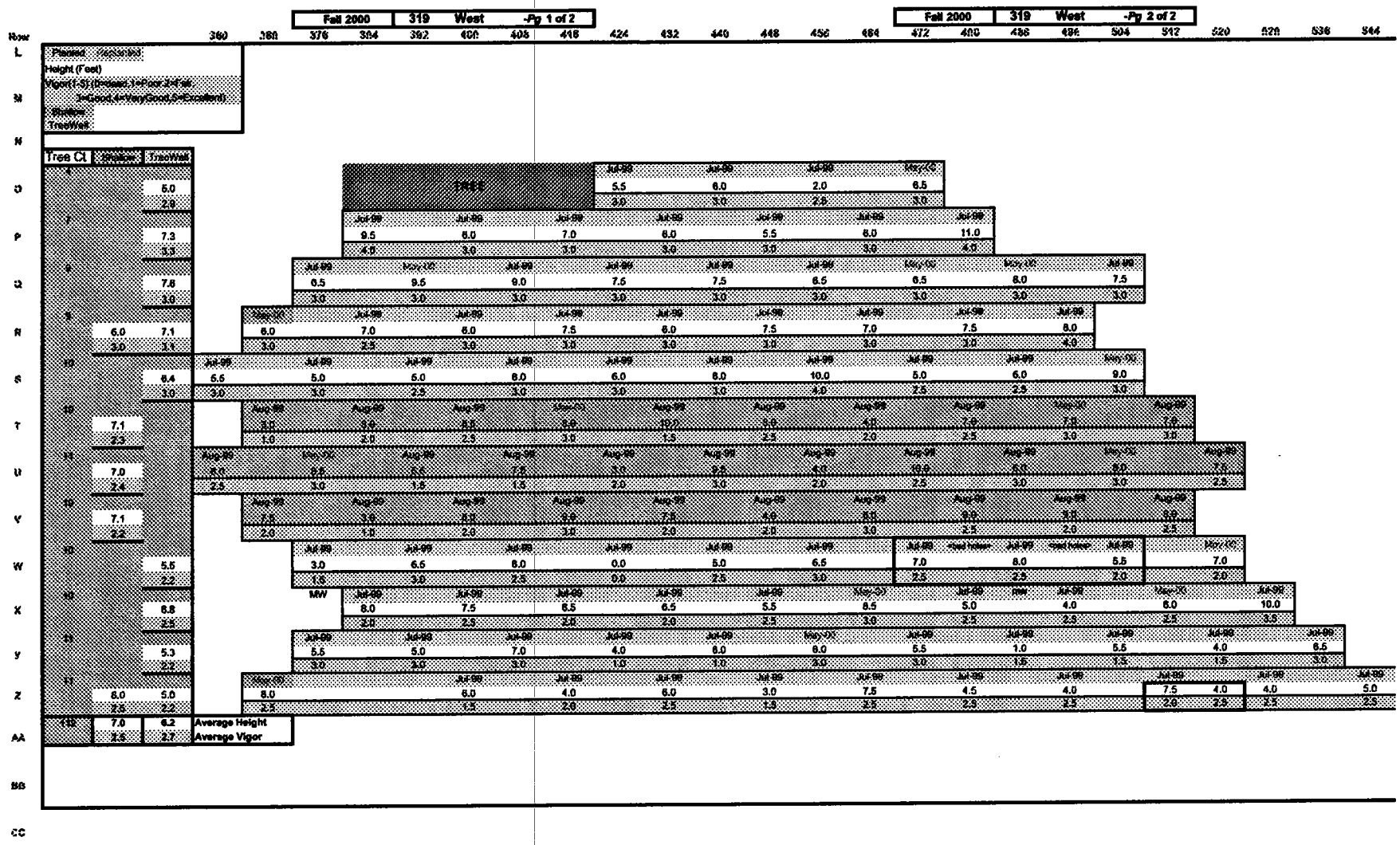
08/29/00

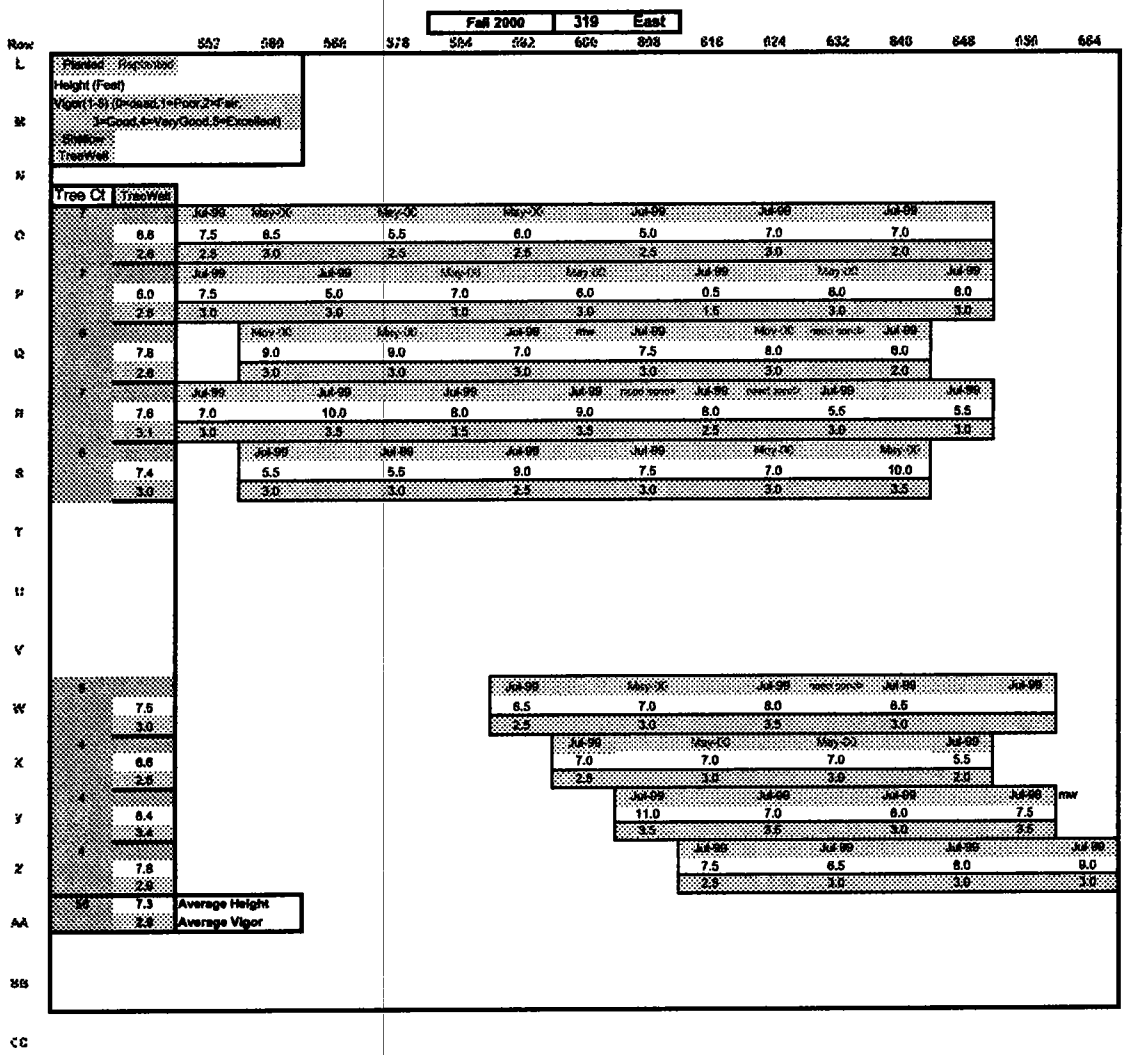


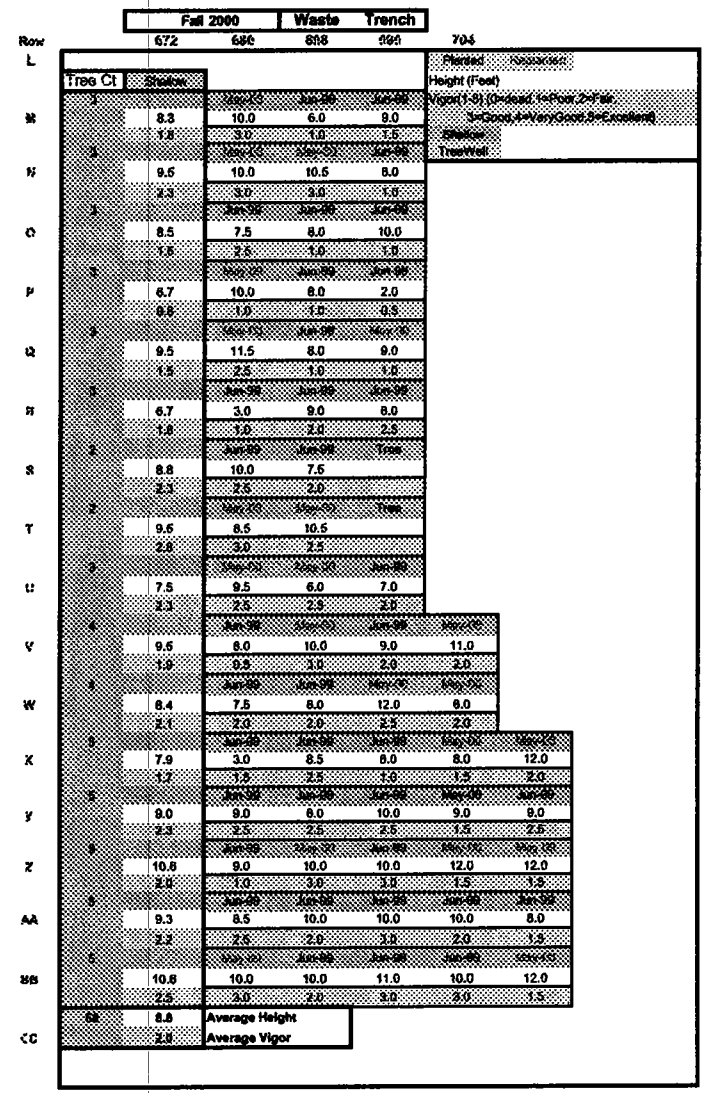

Fall 2000
French Drain
-Pg 1 of 3
Row
TreeCt
Shallow
TreeWell
-25 -20 -15 -10 -5 0 5 10 15 20 25 30 35 40 45
A
B
C
D
E
F
G
H
I
J
K
DD
Planted
Replanted
Jul-99
May-00
Fence
Post
MW
Average Height
Average Vigor
Planted Replanted
Height (Feet)
Vigor(1-5) (0=dead,1=Poor,2=Fair,
3=Good,4=VeryGood,5=Excellent)
Shallow TreeWell

Fall 2000 | French Drain | -Pg 2 of 3

Row	50	55	60	65	70	75	80	85	90	95	100	105	110	115	120	125	130
A	May-00		Jul-99		Jul-99		Jul-99		Jul-99		Jul-99		Jul-99		NeedTree		Jul-99
	9.0		8.0		8.0		9.5		8.0		7.5		7.0				8.0
	3.0		3.0		3.0		3.0		2.5		3.0		2.0				3.0
B		Jul-99		Jul-99		Jul-99		NeedTree		Jul-99		NeedTree		Jul-99		Jul-99	
		8.0		8.0		9.0				7.5				6.0		9.0	
		2.5		3.0		3.0				2.5				2.5		3.0	
C	Jul-99		Jul-99		Jul-99		Control		Control		Jul-99		Jul-99		Jul-99		Jul-99
	7.0		8.0		10.0						7.5		7.5		6.5		9.0
	2.5		2.5		3.0						3.0		3.0		2.5		2.0
D		Jul-99		Jul-99		Jul-99		Control		Jul-99		Jul-99		Jul-99		Jul-99	
		7.0		9.0		7.5				7.0		8.0		9.0		8.0	
		2.0		3.0		3.0				3.0		3.0		3.0		3.0	
E	Jul-99		Jul-99		Jul-99		May-00		Jul-99		May-00		May-00		Jul-99		Jul-99
	8.5		7.0		6.0		10.0		7.0		9.0		11.0		7.5		6.5
	3.0		1.0		3.0		3.5		2.0		3.0		3.0		3.0		3.5
F		Jul-99		MW		Jul-99		May-00		Jul-99		Jul-99		Jul-99		Jul-99	
		8.0				8.0		11.0		3.0		1.0		9.0		8.5	
		3.0				2.5		3.5		3.0		1.0		3.0		3.0	
G	May-00		Jul-99		Jul-99		Jul-99		Jul-99		May-00		Jul-99		Jul-99		Jul-99
	8.0		6.5		8.0		5.0		2.0		11.5		6.3		2.5		8.0
	3.0		2.5		3.0		2.5		2.0		3.0		2.0		3.0		2.5
H		Jul-99		Jul-99	Blacken	Jul-99		Jul-99		Jul-99	Blacken	Jul-99		Jul-99		Jul-99	
		5.5		7.0	Edges	7.0		7.0		6.5	Edges	6.5		7.5		7.0	
		2.5		2.0		2.0		3.0		2.0		2.0		4.0		3.0	
I	Jul-99		Jul-99		Jul-99		Jul-99		Jul-99		May-00		May-00		Jul-99		Jul-99
	7.5		7.0		9.0		7.5		3.0		10.0		9.0		1.5		6.0
	3.0		3.0		3.0		3.0		2.0		3.0		3.0		2.0		3.5
J		Jul-99		Jul-99		Jul-99		MW		Jul-99		Jul-99		Jul-99		Jul-99	
		8.5		8.0		8.0				8.0		6.5		7.5		8.0	
		3.0		2.5		3.0				4.0		4.0		2.5		4.0	
K								MW	Jul-99		Jul-99		Jul-99		Jul-99		Jul-99
									7.5		11.0		0.0		8.5		4.5
									3.5		3.5		0.0		3.0		3.0
DD								Jul-99		Jul-99		Jul-99		Jul-99		May-00	
								12.0		9.0		9.0		7.0		9.0	
								4.0		4.0		2.5		2.5		3.5	


Fall 2000
319
West
-Pg 1 of 2
Fall 2000
319
West
-Pg 2 of 2
Planted
Replanted
Height (Feet)
Vigor (1-5) (1=Dead, 1=Poor 2=Fair
3=Good,4=VeryGood,5=Excellent)
Shallow
TreeWell
Tree Ct
Shallow
TreeWell
Average Height
Average Vigor
TREE
MW


Fall 2000
319
East
Planted
Height (Feet)
Vigor(1-5) (0=dead,1=Poor,2=Fair,3=Good,4=VeryGood,5=Excellent)
Shelter
TreeWell
Tree Ct
TreeWell
Average Height
Average Vigor


Fall 2000
Waste Trench
Row
672
686
698
699
704
L
Trees Ct
Shallow
Planted
Height (Feet)
Vigor(1-5) (0=dead,1=Poor,2=Fair,
3=Good,4=VeryGood,5=Excellent)
Shallow
TreeWell
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3.0
1.0
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N
9.5
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11.0
10.0
12.0
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3.0
3.0
1.5
CC
8.8
Average Height
2.8
Average Vigor